No Net Loss of Fish Habitat: An Audit of Forest Road Crossings of Fish-Bearing Streams in British Columbia, 1996-1999

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Abstract

An audit was conducted to determine whether No Net Loss of fish habitat is being achieved by the forest sector when applying the *Forest Practices Code of British Columbia Act* regulatory standards to intact and deactivated forest road crossings of fish-bearing streams. A total of 46 stream crossings were audited in British Columbia, 23 in the Prince George Forest District and 23 in the Port McNeill Forest District. A total of 12 corrugated metal pipes (CMPs), 16 log culverts (LCs), 12 bridges, and 6 deactivated crossings were evaluated. At each crossing site, impacts to fish habitat were recorded. Impacts to fish habitat included loss of stream habitat due to encroachment, loss of benthic habitat due to sediment inundation or non-embedded corrugated metal pipes, loss of riparian habitat due to the crossing structure, loss of riparian habitat due to the road & right-of-way, or loss of potential upstream habitat due to an impassable crossing. The average loss of stream habitat, including loss of benthic habitat, per crossing was 24.5 m^2 for the Prince George Forest District and 4.8 m^2 for the Port McNeill Forest District. The average loss of stream habitat by crossing type was 42.5 m^2 for CMPs, 1.2 m^2 for LCs, 11.5 m^2 for bridges, and 0.8 m^2 for deactivated crossings. Four CMP crossings were impassable resulting in a 6 km loss of potential upstream habitat. The average total loss of fish habitat (including riparian losses) by crossing type was 708.5 m^2 for CMPs, 414.2 m^2 for LCs, 575.4 m^2 for bridges, and 352.5 m^2 for deactivated crossings. Considering that 3000 to 6000 stream crossings are installed in British Columbia on an annual basis, the potential for cumulative impacts to fish habitat is high. Agencies responsible for the protection of fish habitat and stream crossings should adopt the position of not allowing the installation of CMPs on fish-bearing streams. The stream crossings evaluated in the Port McNeill Forest District demonstrate that there are better alternatives in terms of both providing fish passage and protecting habitat at crossing sites, including LCs and bridges. Attempts should be made to retain riparian vegetation adjacent to stream crossings as a means of controlling sediment and erosion concerns and streambank destabilization.

Résumé

Une vérification a été effectuée pour déterminer si le secteur forestier ne causait aucune perte nette dans l'habitat des poissons, en suivant les normes réglementaires de la *Forest Practices Code of British Columbia Act* dans le cas des traversées de chemin de forêt intactes et désactivées pour les cours d'eau à poissons. Quarante-six traversées ont été vérifiées en tout en Colombie-Britannique, 23 dans le district forestier de Prince George et 23 dans celui de Port McNeill. On a examiné 12 traversées à tuyau de métal ondulé (TMO), 16 buses de bois (BB), 12 ponceaux et 6 traversées de désactivation. Les répercussions sur l'habitat des poissons ont été consignées à chaque emplacement de traversée. Ces répercussions comprenaient la perte d'habitat lotique par empiètement, la perte d'habitat benthique par l'accumulation de sédiments ou l'utilisation de tuyaux en métal ondulé non enfouis, la perte d'habitat riverain résultant de la structure de la traversée, la perte d'habitat riverain résultant de la présence d'un chemin et du droit de passage, ou la perte d'un habitat amont potentiel causée par une traversée infranchissable. L'étendue moyenne de l'habitat lotique perdu, y compris l'habitat benthique, était de 24,5 m^2 par traversée dans le district forestier de Prince George et de 4,8 m^2 dans celui de Port McNeill. La perte moyenne d'habitat lotique par type de traversée était de 42,5 m^2 pour les TMO, 1,2 m^2 pour les BB, 11,5 m^2 pour les ponceaux et 0,8 m^2 pour les traversées de désactivation. Quatre traversées à TMO étaient infranchissables, ce qui a entraîné une perte d'habitat amont potentiel s'étendant sur 6 km. L'étendue totale moyenne des pertes d'habitat des poissons (y compris les pertes d'habitat riverain) par type de traversée était de 708,5 m^2 pour les TMO, 414,2 m^2 pour les BB, 575,4 m^2 pour les ponceaux et 352,5 m^2 pour les traversées de désactivation. Compte tenu du fait qu'on installe de 3 000 à 6 000 traversées annuellement en Colombie-Britannique, le potentiel des répercussions cumulées sur l'habitat des poissons est élevé. Les organismes responsables de la protection de l'habitat des poissons et des traversées devraient interdire l'installation de TMO sur les cours d'eau à poissons. Les traversées examinées dans le district forestier de Port McNeill démontrent qu'il existe de meilleures façons de créer des passes à poisson et de protéger l'habitat aux sites de traversée, y compris les buses de bois et les ponceaux. Il faudrait tenter de conserver la végétation riveraine voisine des traversées pour contrôler les sédiments, l'érosion et la déstabilisation des berges.

100-06620/

1.0 Introduction

Knowledge of the impacts that stream crossings have on fish and fish habitat has long been established (Dane 1978; Furniss *et al.* 1991). Stream crossings can result in increased sedimentation in streams, create alterations in channel morphology, and become potential barriers to fish migration. Stream crossings can also result in direct losses of fish habitat -- channel loss, benthic loss, riparian loss -- by the ecological footprint they leave on the stream environment. The number of stream crossings within British Columbia is constantly increasing with new road development. The forestry sector is the primary industry responsible for the majority of road construction in British Columbia. It is estimated that there is a network of 170,000 km of Forest Service roads providing access to the provincial forests, not including an additional 150,000 km of old abandoned (non-status) roads and secondary roads that access cut blocks and other forest management sites (British Columbia Ministry of Forests, 1998). That translates into at least 225,000 road-stream crossings on crown forest land (Geographic Data BC, Terrain Resource Information Management 1979-1988, pers. comm.). Each year, an additional 5,000 to 10,000 km of roads are constructed to meet the needs of the forestry sector.

Over the past decade, there has been an evolution of environmental legislation and policy directing the forestry sector to address the negative impacts that stream crossings and other forestry practices are having on fish habitat. In 1987, the first edition of the *British Columbia Coastal Fisheries/Forestry Guidelines* (CFFG) was produced jointly between the British Columbia Ministry of Forests (MOF), the British Columbia Ministry of Environment, Lands and Parks (MELP), Fisheries and Oceans Canada (DFO) and the Council of Forest Industries to address environmental impacts due to forestry practices. The CFFG advised that crossing structures were to minimize the loss of productive capacity of fish habitats by maintaining the width and gradient of fish-bearing streams, recommending the use of wooden culverts or pipe arches for fish passage (MOF *et al.* 1987). Tripp (1992, 1994) reviewed the application and effectiveness of the CFFG in protecting fish habitat and established that environmental damage and inadequacies continued within the forestry sector in spite of the guidelines.

In 1995, the *Forest Practices Code of British Columbia Act* (FPC) was enacted, which aimed to enhance the level of environmental protection. The preamble to the FPC supports the sustainable use of the forests and states that sustainable use includes, "conserving biological diversity, soil, water, fish, wildlife, scenic diversity and other forest resources" (FPC 1995). The FPC further prevents the deposit of debris or erodible soil into streams and ensures safe fish passage through stream crossings (FPC Forest Road Regulations, Part 2-Section (9), Part 3-Section (7)). In 1997, a working draft of the *Stream Crossing Guidebook for Fish Streams* (SCG) was released under the FPC (Poulin and Argent 1997). The guidebook was intended to assist practitioners in interpreting the FPC and provide guidance in choosing, designing, and applying environmentally-sound mitigative strategies to crossing structures on fish-bearing streams. This working draft was endorsed by DFO, MOF, MELP, and the British Columbia Ministry of Employment and Investment.

The SCG has also been used to facilitate the stream crossing approval process for DFO and/or MELP habitat staff. Section 35(1) of the *Fisheries Act* prevents the harmful alteration, disruption, or destruction of fish habitat unless authorized by DFO's habitat management staff (Section 35(2)). While in theory each and every crossing on a fish-bearing stream may represent a harmful alteration, disruption, or destruction of fish habitat, in practice the sheer number of stream crossings installed (or deactivated) within a given Forest District in a year precludes the possibility of authorizing every stream crossing. Instead, DFO and/or MELP issue Letters of Advice that provide industry with recommended mitigative measures to avoid

Fisheries Act violations at stream crossings. Regulatory agencies often direct proponents to construct, maintain, and deactivate stream crossings to the specifications of the SCG.

Since the advent of the FPC in 1995 and the SCG in 1997, DFO's Habitat and Enhancement Branch refocused its forestry involvement to landscape and higher level planning and moved away from rigorous review of individual stream crossing referrals, relying on the provisions of the FPC to protect fish and fish habitat. The guiding principle of DFO's conservation efforts is to achieve a No Net Loss (NNL) of the productive capacity of fish habitat (DFO 1986); the Department strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis. Concern has been raised by DFO habitat management staff that the NNL conservation goal is not being achieved with respect to stream crossings.

In light of the aforementioned, an audit was conducted to determine whether the Department's goal of No Net Loss of fish habitat is being met by the forestry sector with respect to post-FPC intact and deactivated stream crossings. Results provided from this audit are used to determine the effectiveness of the FPC in protecting fish habitat and to provide recommendations to habitat management staff on improving habitat protection at stream crossings. Results may also be used to provide consistency within DFO in terms of addressing fish habitat impacts from stream crossings and to provide input into the development and improvement of current stream crossing best management practices.

2.0 Methods

2.1 Site Selection and Description

The audit examined intact and deactivated crossings on S2, S3, and S4 fish-bearing streams[1] (as defined in the *FPC Riparian Management Area Guidebook*, 1995) within selected fish-bearing watersheds of the Prince George Forest District (PGFD) and the Port McNeill Forest District (PMFD) in British Columbia. These Forest Districts, represented in Figure 1, were selected to provide a representation of both coastal and interior BC forestry practices and ecology and to provide a broad representation of forest licensees. Study areas within the Forest Districts were selected based on location, post-FPC (1996-2000) forest development activity, and fisheries values, but were not limited to salmon-bearing watersheds.

Figure 1. The Prince George Forest District and the Port McNeill Forest District.

[1]S2 streams have an average channel width of >5-20 m; S3 streams have an average channel width of 1.5-5 m; S4 streams have an average channel width of <1.5 m.

2.1.1 Prince George Forest District Study Areas

Three study areas were selected within the PGFD; each study area was made up of six mapsheets on the BC 1:20,000 mapping grid, representing an area of approximately 872 km^2. The following are the PGFD study areas (Figure 2):

PG-1 Salmon River Study Area

Mapsheet Numbers: 93J015
93J016
93J025
93J026
93J027
93J035

Ecoprovince: Sub-Boreal Interior
Ecoregion: Fraser Basin
Ecosection: Nechako Lowland

The Salmon River Study Area lies within the sub-boreal spruce biogeoclimatic zone which consists of hybrid Englemann-white spruce and subalpine fir, with abundant stands of lodgepole pine and wetlands. Precipitation ranges from 500 to 600 mm, with 60% of the precipitation falling from May through September. Within these months, evapotranspiration is high due to dry summers and much of the rainfall does little to contribute to streamflow. Streamflows are highest after snowmelt. Soils consist of glacio-lacustrine deposits. The fish species present in the Salmon River watershed include chinook salmon, rainbow trout, bull trout, burbot, Rocky Mountain whitefish, and kokanee (DFO, 1991).

PG-2 McGregor/Herrick River Study Area

Mapsheet Numbers: 93I023
93I025
93I032
93I033
93I034
93I035

Ecoprovince: Sub-Boreal Interior
Ecoregion: Fraser Basin and Central Canadian Rocky Mountains
Ecosection: MacGregor Plateau and Hart Ranges

The McGregor/Herrick River Study Area lies within the sub-boreal spruce and Engelmann spruce-subalpine fir biogeoclimatic zones. These zones consist of Englemann spruce, subalpine fir, and lodgepole pine. This area has greater annual precipitation (~820 mm) than the Salmon River Study Area, and streamflows tend to be maintained throughout the year. Streamflows are highest after snowmelt. Soils in this area are particularly unstable glacio-lacustrine soils. The fish species present in the McGregor/Herrick watersheds include chinook salmon, bull trout, rainbow trout, Rocky Mountain whitefish, and burbot (DFO 1991).

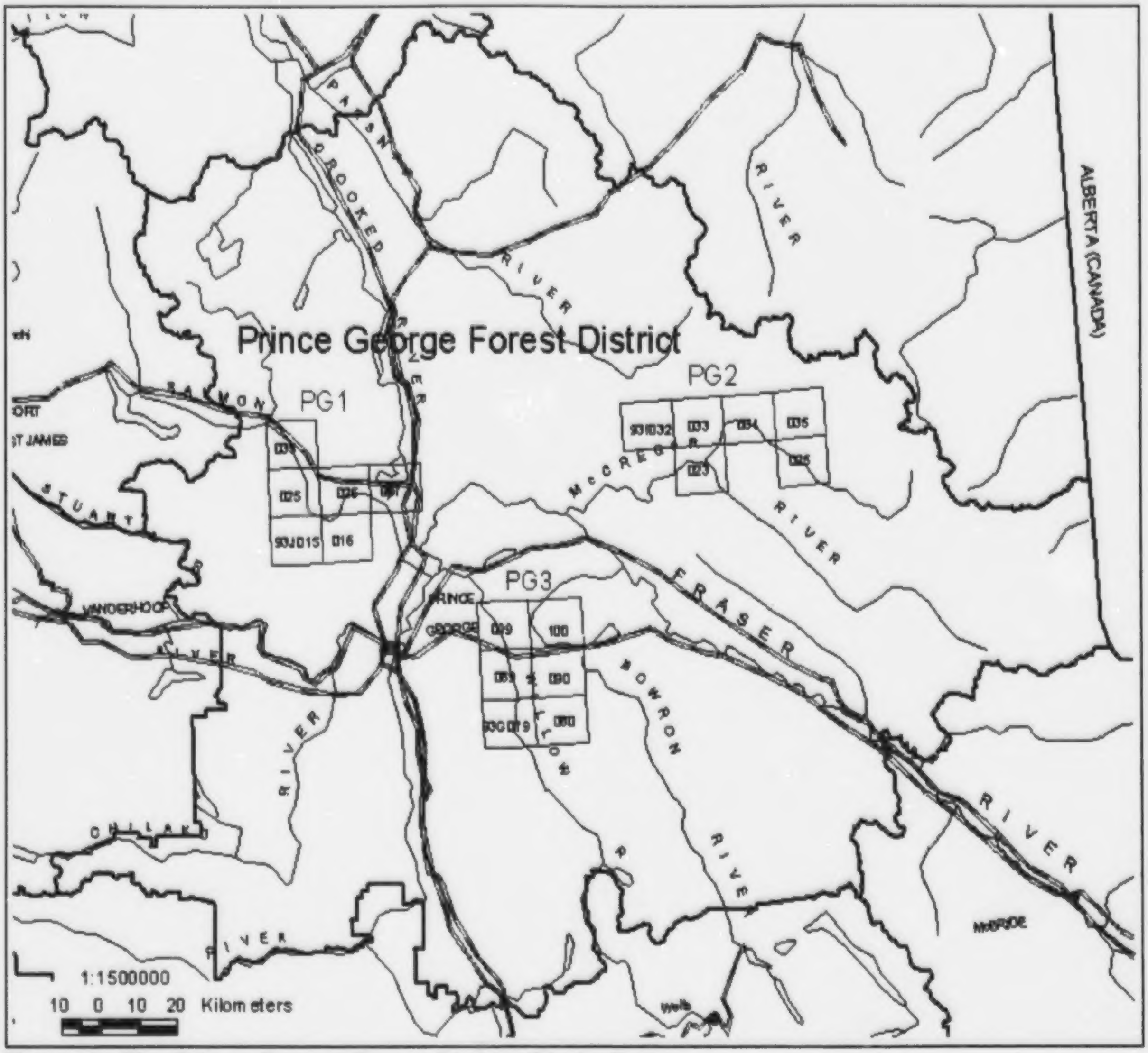

Figure 2. The Prince George Forest District Study Areas.

PG-3 Willow/Bowron River Study Area

Mapsheet Numbers: 93G079
93G080
93G089
93G090
93G099
93G100

Ecoprovince: Southern Interior Mountains
Ecoregion: Columbia Mountains and Highlands
Ecosection: Bowron Valley

The Willow/Bowron River Study Area lies within the sub-boreal spruce and Engelmann spruce-subalpine fir biogeoclimatic zones. These zones consist of Englemann spruce, subalpine fir, and lodgepole pine. This area has an annual precipitation of 1000 to 1100 mm. Streamflows are highest after snowmelt and tend to be highly variable throughout the summer months, depending on rainstorm events. Soils in this area consist of glacio-lacustrine deposits. The fish species present in the Willow and Bowron watersheds include chinook salmon, sockeye salmon, bull trout, rainbow trout, and Rocky Mountain whitefish (DFO 1991)

2.1.2 Port McNeill Forest District Study Areas

Two study areas were selected within the PMFD; each study area was made up of 4 mapsheets of the BC mapping grid, representing an area of approximately 582 km^2. Only two study areas, comprised of 4 mapsheets each, were required for the PMFD because of the higher density of streams per unit area in coastal BC. The following are the PMFD study areas (Figure 3):

PM-1 Nahwitti/San Josef/MacJack River Study Area

Mapsheet Numbers: 102I060
102I070
102I080
92L071

Ecoprovince: Coast and Mountains
Ecoregion: Western Vancouver Island
Ecosection: Nahwitti Lowland

PM-2 Rupert Inlet and Waukwass/Nimpkish River Study Area

Mapsheet Numbers: 92L045
92L053
92L054
92L055

Ecoprovince: Coast and Mountains
Ecoregion: Western Vancouver Island
Ecosection: Nahwitti Lowland

Both the Nahwitti/San Josef/MacJack River study area and the Rupert Inlet and Waukwass/Nimpkish River study area lie within the coastal western hemlock biogeoclimatic zone. It consists primarily of western hemlock and amabilis fir. This area has an annual precipitation of 2300 to 4600 mm which is much greater than that of the PGFD study areas. Streamflows are maintained throughout the year. The fish species present in both of these study areas include sockeye salmon, chinook salmon, coho salmon, pink salmon, chum salmon, steelhead, cutthroat trout, Dolly Varden, brook trout, rainbow trout, and kokanee (DFO 1991).

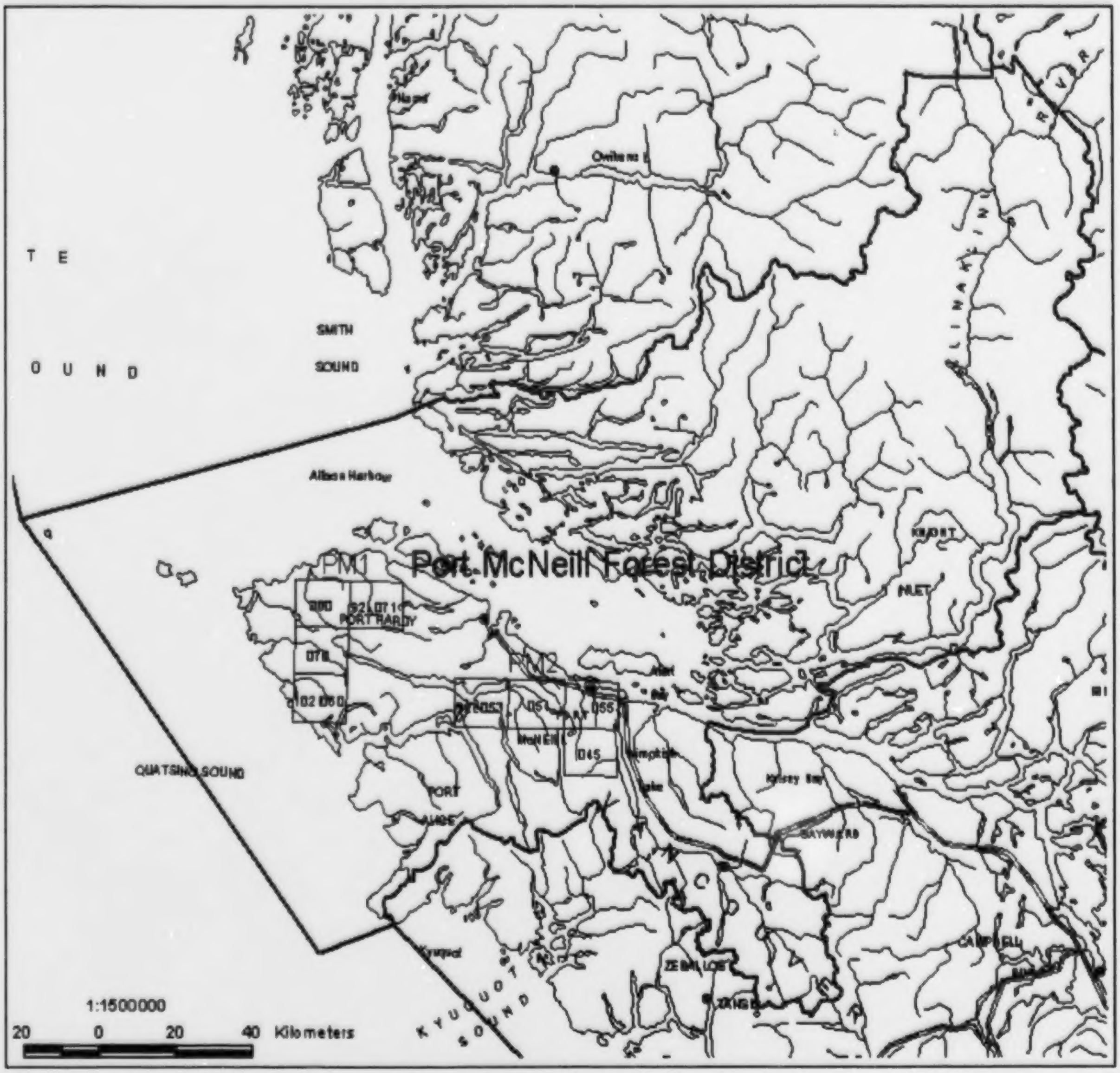

Figure 3. The Port McNeill Forest District Study Areas.

2.3 Information Collection

For each study area in the PGFD, silviculture prescriptions for post-FPC cutblocks greater than 10 hectares were reviewed for the relevant stream crossing and fisheries information. If a silviculture prescription indicated that a crossing on a S2, S3, or S4 stream was located within or adjacent to a cutblock, the crossing was included in the audit. Forest Development Plan (FDP) maps -- maps identifying proposed cutblocks, road destinations, and stream crossings -- were also reviewed so that crossings on post-FPC Forest Service roads or secondary roads could be identified and included in the audit. Over 40 potential crossing sites were identified in the PGFD study areas.

For each study area in the PMFD, FDP maps were used to identify stream crossings to be audited. Silviculture prescriptions and road permit files were used only to supplement the fisheries information on the FDP maps and to clarify the crossing location. Over 30 potential sites were identified in the PMFD study areas.

Deactivated crossings were also included in the audit. Accessibility of a particular crossing, and whether or not it had been deactivated, could only be determined in the field. An equal number of stream crossing surveys (n = 23) were performed in each Forest District.

2.3 Measuring Fish Habitat Loss

Fish habitat is legally described in the *Fisheries Act* as:

> "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes"

For the purpose of this audit, fish habitat losses were divided into two categories: stream habitat loss and riparian loss. Stream habitat loss was further divided into three sub-categories -- habitat loss due to impassable crossing, habitat loss due to encroachment, and benthic loss. Riparian loss was divided into two sub-categories -- riparian loss due to road and riparian loss due to crossing structure. Figure 4 demonstrates an approximate areal representation of the different sub-categories of fish habitat loss. The sub-categories were defined and measured as follows:

Habitat loss due to impassable crossing (m): the length of potential stream habitat lost upstream of an impassable crossing was determined by on-sight measurement and/or estimation using a TRIM mapsheet (Terrain Resource Information Management, MELP, 1994). Stream reaches with gradients of greater than 20% were not considered as fish-bearing streams and were not included habitat (as per the *FPC Riparian Management Area Guidebook*, 1995). Impassable stream crossings can be caused by excessive water velocities, lack of water depth, elevated inlets and outlets, and debris obstructions. Barriers due to water velocity and water depth were based on the SCG's criteria for juvenile fish passage (Poulin and Argent 1997). Note that the measurement of potential habitat loss from the TRIM maps was conservative because both the area of the channel and the area of the tributaries flowing into the stream above the impassable crossing were not included in the measurement of potential habitat lost due to inaccessibility.

Habitat loss due to encroachment (m^2): the amount of stream habitat lost due to channel encroachment, including natural stream banks and substrates as well as any useable spawning and/or rearing habitat and food production capabilities within the crossing's ecological footprint. Habitat loss due to encroachment was measured by multiplying the difference between the channel width where the encroachment exists and the average bankful width (see Section 2.4.5) by the length of the encroachment; for example, if a 20 m culvert has a span of 1m and it has been placed in a channel with a average bankful width of 2m, the loss of habitat due to encroachment will be 20 m X 1 m = 20 m^2. Habitat loss due to encroachment is represented by area A in Figure 4.

Benthic loss (m^2): the amount of benthic habitat lost or rendered unproductive from sediment inundation within the active channel and/or non-embedded crossing structures (e.g. culverts that rest on the streambed). Benthic habitat represents the substrate that supports the community of algae and invertebrates which provide food for fish. Benthic habitat may also represent potential spawning areas for adults and/or rearing areas for juveniles. Note that benthic loss and habitat loss due to encroachment were measured separately and did not overlap (i.e. losses were not counted twice). Benthic loss is represented by area B in Figure 4.

Riparian loss due to road (m^2): the amount of riparian vegetation lost due to the road and the right-of-way (ROW). When measuring the riparian loss due to road, the measured width of the clearing was limited to 15 m perpendicular and away from the stream bank, as per the *Land Development Guidelines* (Chilibeck *et al.* 1992). However, if the stream was located within a cutblock, the measured width of the clearing, perpendicular and away from the stream bank, was limited by the width of a riparian management zone retained on the stream, if any (not exceeding 15 m -- see *FPC Riparian Management Area Guidebook*, 1995). Riparian loss due to road is represented by area C in Figure 4.

Riparian loss due to crossing (m^2): the amount of riparian vegetation permanently lost due to the crossing structure. This included riprap and timber placement adjacent to the crossing structure but did not include the area lost due to the crossing approach (i.e. the road). The purpose of this measurement was to compare riparian losses incurred by different crossing types. Note that riparian loss due to road and riparian loss due to crossing were measured separately and did not overlap (i.e. losses were not counted twice). Riparian loss due to crossing is represented by area D in Figure 4.

It should be noted that no attempt was made at measuring the loss of productive capacity. It is assumed that the loss of habitat as measured in this audit resulted in a loss of productive capacity -- the maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend. Also, no attempts were made to quantify the quality of habitat at different crossing sites; however, stream habitat characteristics were recorded (see below).

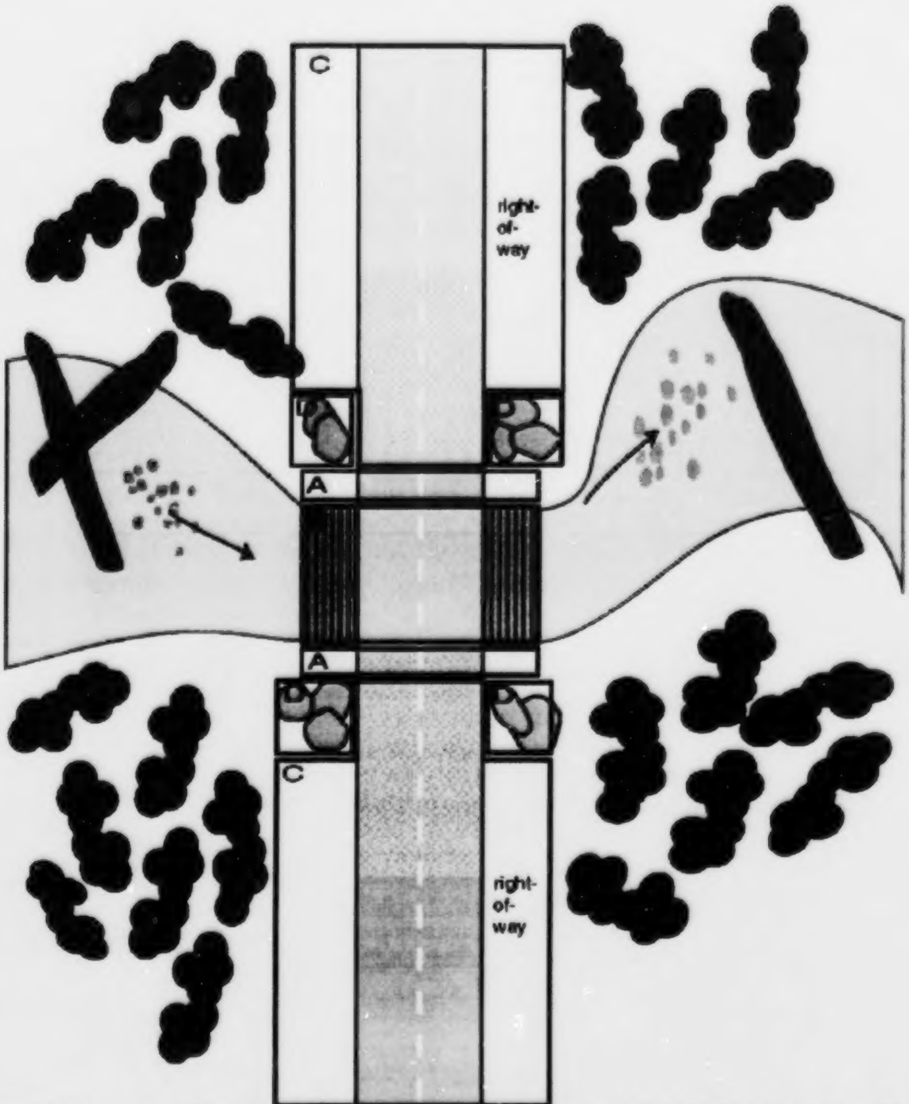

Figure 4. A schematic diagram demonstrating an approximate areal representation of the different sub-categories of potential fish habitat loss. Area A represents habitat loss due to encroachment (m^2); area B represents benthic loss (m^2); area C represents riparian loss due to road (m^2); and area D represents riparian loss due to crossing (m^2). Note that habitat loss due to impassable crossing (m) is not represented in this diagram.

2.4 Site Audits

The PGFD site audits were conducted from August 15th, 1999 to August 29th, 1999. The PMFD site audits were conducted from December 12th, 1999 to December 18th 1999. At each crossing location, a NNL Stream Crossing Audit Form (Appendix 1) was completed. The NNL Stream Crossing Audit Form consisted of Site Information, a Crossing Survey, a Habitat Survey, and a Photographic Record. The Crossing Survey varied depending on the crossing type -- culvert, bridge, or deactivated crossing. The Habitat Survey methods were primarily derived from the *Fish Habitat Inventory and Information Program Stream Survey Field Guide* (DFO and MELP, 1989). The fields of the NNL Stream Crossing Audit Form and the methods employed to collect the appropriate information are summarized in the following sections.

2.4.1 Site Information

Crossing Identification: each crossing was identified by the Forest District (PG or PM), the study area within the district (1, 2, or 3), and a number representing the chronological order in which the crossing was surveyed; for instance, crossing PG2-4 represents the fourth crossing surveyed in study area 2 of the PGFD.

Date: the date the survey was conducted.

Trim Map: the TRIM map sheet on which the crossing is located.

UTM Zone & UTM co-ordinates: the zone of the UTM co-ordinates and the easting and northing of the UTM co-ordinates

Watershed Name: the watershed name was obtained from TRIM and FDP maps or BC Watershed Atlas (1998).

Forest Licensee: the forest licensee responsible for the stream crossing at the time of construction was obtained from file search.

Cutting Permit and Block Number: the cutting permit and block number was obtained from file search.

Road Name (No.): the road name was obtained from file search.

Road km: the road km was recorded from the vehicle odometer or FDP map.

Access: access was recorded as truck, atv, or foot.

2.4.2 Culvert Crossing Survey

Type: the culvert type was identified by visual observation. Only two culvert types were observed in this study -- corrugated metal pipes (CMPs) and log culverts (LCs).

Length (m): the length of culvert was measured with a surveyor's tape.

Span (mm): the span of culvert was measured with a surveyor's tape.

Embedment (m): the embedment was measured using a metre stick.

Culvert Water Depth (m): the depth of the water within the culvert was measured using a metre stick.

Outlet Water Velocity (m/s): the outlet water velocity was measured with a flowmeter (Swoffer Instruments Inc.; Model 2100). The flow at both the centre and sides of the culvert was measured, and the lower value was used to determine fish passage.

Culvert Gradient (%): the culvert gradient was measured with a level and surveyor's rod.

Inlet Condition: the inlet condition was determined by visual observation. Scouring, fill failure, culvert damage, and blockage were noted.

Outlet Condition: the outlet condition was determined by visual observation. Scouring, fill failure, culvert damage, and blockage was noted. If necessary, the outlet pool depth and outlet vertical drop were also measured with a metre stick.

Internal Condition: the internal condition was determined by visual observation. Blockage and culvert damage were noted.

Bank Stability: the bank stability and potential for surface erosion adjacent to inlet and outlet of crossing was determined by field observations. Surface erosion potential was described and possible prescriptions were noted.

Encroachment Ratio: the encroachment (if any) ratio was measured using a surveyor's tape; the encroachment ratio represents the culvert span relative to the representative bankful width. A ratio less than 1:1 represents an encroachment.

Habitat Loss due to encroachment (m^2): the habitat loss due to encroachment (if any) was measured with a surveyor's tape, multiplying the difference between the channel width where the encroachment exists and the average bankful width by the length of the encroachment.

Riparian Loss due to crossing (m^2): the loss of riparian habitat (if any) due to the crossing was measured using a surveyor's tape, representing a permanent loss of riparian vegetation due to the crossing structure itself, excluding the road approach.

Riparian Loss due to road (m^2): loss of riparian habitat due to the road and the right-of-way was measured using a surveyor's tape.

Habitat Loss due to impassable crossing (m): length of potential habitat lost upstream of crossing was measured on-sight and/or estimated using a TRIM mapsheet. Impassable crossings based on factors such as water velocity, inlet/outlet drops, water depth, and blockage.

Benthic Loss (m^2): loss of benthic habitat was measured using a surveyor's tape and represented the area of streambed that is rendered unproductive from sediment inundation and/or a non-embedded crossing structure.

2.4.3 Bridge Crossing Survey

Bridge Length (m): the bridge length was obtained using a surveyor's tape.

Bridge Width (m): the bridge width was obtained using a surveyor's tape.

Clearance (m): the clearance was obtained using a surveyor's rod.

Superstructure: the superstructure construction was determined by visual observation.

Abutments: abutment construction was determined by visual observation.

Encroachment Ratio: the encroachment ratio (if any) was measured using a surveyor's tape; the encroachment ratio represents the bridge abutment span to the representative bankful width. A ratio less than 1:1 represents an encroachment.

Outlet Water Velocity (m/s): the outlet water velocity was measured with a flowmeter (Swoffer Instruments Inc.; Model 2100). Average velocity along a cross-sectional transect was calculated.

Note that bank stability, habitat loss due to encroachment (m^2), riparian loss due to crossing (m^2), and riparian loss due to road (m^2) were measured and recorded as described in the Culvert Crossing Survey above.

2.4.4 Deactivation Survey

Unstable sidecast fill pulled back to an appropriate angle or the angle of the natural streambanks (Yes/No): determined by field observations.

Soil erosion control (Yes/No): determined by field observations.

Re-vegetation of banks (Yes/No): determined by field observations.

Ditches blocked appropriately (Yes/No): determined by field observations.

Note that bank stability, water velocity, habitat loss due to encroachment (m^2), riparian loss due to crossing (m^2), and riparian loss due to road (m^2) were measured and recorded as described in the Culvert Crossing Survey above.

2.4.5 Habitat Survey

Stream Classification: the stream classification as per the *FPC Riparian Management Area Guidebook* (1995) was determined from file review and through field verification.

Fish Habitat Classification: habitat type (spawning and/or rearing) was determined by visual observation.

Stream Dimensions (m): the stream dimensions included wetted width, bankful width, bankful depth, water depth. Stream dimensions were measured using a metre stick and/or surveyor's tape at six different locations -- three upstream and three downstream of the crossing. Note that stream dimensions were not measured where unnatural channel widening and/or scouring resulted from a crossing structure.

Channel Morphology: the channel morphology was determined visually for a 10x bankful width section upstream and downstream of the crossing.

Stream Gradient (%): the stream gradient was measured with a clinometer or a level and surveyor's rod.

Bed Materials (%): an estimate of the percent composition of the bed materials was determined by visual observation. The percentage of fines (<2 mm), gravels (2-64 mm), cobbles (64-256 mm), boulders (>256 mm), and bedrock was recorded.

Large Woody Debris Cover (%): the percentage of large woody debris was estimated by visual observation. The percentage included both superficial and embedded large woody debris.

Bank Stability: bank stability was determined by field observations over a 10x bankful width section upstream and downstream of the crossing.

Water Velocity (m/s): the average water velocity was measured with a flowmeter (Swoffer Instruments Inc.; Model 2100) along a transect, perpendicular to the streambanks at three locations above the crossing and three locations below the crossing.

2.4.5 Photographic Record

A photographic record was made at each crossing. The record included photographs of the channel upstream and downstream of the crossing as well as the inlet and outlet of the crossing structure. Additional photographs taken at the crossing sites included upstream and downstream banks adjacent to the crossings and sediment control techniques.

3.0 Results

3.1 Summary Information

A total of 46 stream crossings were surveyed, 23 in each Forest District. Over 40 crossings initially selected from the file search of the study could not be included in the study because they were either inaccessible, had not been built, or were built over streams that had been misclassified as fish habitat. The crossing types surveyed included corrugated metal pipes (CMPs), log culverts (LCs), bridges, and deactivations. A breakdown of crossing type by study area is shown in Table 1.

Table 1. Summary of crossing types by study area.

Study Area	No. of CMPs	No. of LCs	No. of Bridges	No. of Deactivations	Total No. of Crossings
PG-1	2	-	2	2	6
PG-2	8	-	2	2	12
PG-3	2	1	-	2	5
PM-1	-	11	4	-	15
PM-2	-	4	4	-	8
Total	12	16	12	6	46

Table 1 demonstrates that the CMPs (n=12) surveyed were located in the PGFD and that the majority of the crossing structures in the PMFD were LCs (n=15). All of the deactivated crossings surveyed were found in the PGFD. There were more bridges surveyed in the PMFD (n=8) than in the PGFD (n=4). With respect to crossing type and stream classification, S4 streams were crossed using CMPs and LCs, only. CMPs, LCs, and bridges were used to cross S3 streams. Bridges were used exclusively as the crossing structure of S2 streams due to their channel width (5-20 m). Table 2 illustrates the crossing types used on the different stream classes.

Table 2. Summary of crossing types by stream classification

Crossing Type	S2	S3	S4	Total
CMP	-	7	5	12
LC	-	11	5	16
Bridge	4	8	-	12
Deactivation	2	3	1	6
Total	6	29	11	46

The summary of habitat losses for the PGFD and the PMFD crossing structures are presented in Tables 3 and 4, respectively.

Table 3. Summary of fish habitat losses for the surveyed crossings of the PGFD.

Crossing ID	Crossing Type	Habitat Loss due to Impassable crossing (m)	Habitat Loss due to encroachment (m^2)	Benthic Loss (m^2)	**Total Stream Habitat Loss (m^2)**	Riparian Loss due to crossing (m^2)	Riparian Loss due to road (m^2)	**Total Habitat Loss (m^2)**
PG1-1	CMP	0	4	10.8	**14.8**	0	360	**374.8**
PG1-2	Deact.	0	0	0	**0**	300	240	**540**
PG1-3	Bridge	0	5.7	0	**5.7**	499.5	156.4	**661.6**
PG1-4	Deact.	0	0	0	**0**	188	257	**445**
PG1-5	Bridge	0	4	0	**4**	242	150	**396**
PG1-6	CMP	0	1.8	9.6	**11.4**	0	300	**311.4**
PG2-1	CMP	0	84	74	**158**	0	750	**908**
PG2-2	CMP	3000	60	17	**77**	0	915	**992**
PG2-3	Bridge	0	30	0	**30**	123	777	**930**
PG2-4	CMP	0	9.5	17.6	**27.1**	0	900	**927.1**
PG2-5	CMP	0	9.9	27	**36.9**	90	810	**936.9**
PG2-6	CMP	1000	16.9	13	**29.9**	0	600	**629.9**
PG2-7	CMP	0	23	41.4	**64.4**	57	900	**1021.4**
PG2-8	CMP	1500	25	23.4	**48.4**	16	734	**798.4**
PG2-9	CMP	0	7.7	8.4	**16.1**	0	870	**886.1**
PG2-10	Deact.	0	0	5	**5**	0	540	**545**
PG2-11	Bridge	0	0	0	**0**	0	630	**630**
PG2-12	Deact.	0	0	0	**0**	0	285	**285**
PG3-1	Deact.	0	0	0	**0**	0	0	**0**
PG3-2	LC	0	7.7	0	**7.7**	11.5	540	**559.2**
PG3-3	CMP	500	4.5	4.5	**9**	0	270	**279**
PG3-4	Deact.	0	0	0	**0**	0	300	**300**
PG3-5	CMP(2)	0	7.8	9.2	**17**	0	420	**437**
Total	**All**	**6000**	**301.5**	**260.9**	**562.4**	**1527**	**11704.4**	**13793.8**
Average	**All**	**260.9**	**13.1**	**11.3**	**24.5**	**66.4**	**508.9**	**599.7**
Average	**CMP**	**461.5**	**21.9**	**19.7**	**42.5**	**22.0**	**662.0**	**725.5**
Average	**LC**	**0.0**	**7.7**	**0.0**	**7.7**	**11.5**	**540.0**	**559.2**
Average	**Bridge**	**0.0**	**3.2**	**0.0**	**3.2**	**247.2**	**312.1**	**562.5**
Average	**Deact.**	**0.0**	**1.9**	**0.6**	**2.6**	**63.9**	**337.8**	**404.2**

Table 4. Summary of fish habitat losses for the surveyed crossings of the PMFD.

Crossing ID	Crossing Type	Habitat Loss due to Impassable crossing (m)	Habitat Loss due to encroachment (m^2)	Benthic Loss (m^2)	**Total Stream Habitat Loss (m^2)**	Riparian Loss due to crossing (m^2)	Riparian Loss due to road (m^2)	**Total Habitat Loss (m^2)**
PM1-1	LC	0	0	0	**0**	0	0	**0**
PM1-2	Bridge	0	0	0	**0**	16	390	**406**
PM1-3	LC	0	7.8	0	**7.8**	8	240	**255.8**
PM1-4	Bridge	0	83.5	0	**83.5**	20	485	**588.5**
PM1-5	LC	0	0	0	**0**	4	290	**294**
PM1-6	Bridge	0	14.9	0	**14.9**	148	495	**588.5**
PM1-7	LC	0	0	0	**0**	0	645	**645**
PM1-8	LC	0	1.4	0	**1.4**	0	519	**520.4**
PM1-9	LC	0	0	0	**0**	0	150	**150**
PM1-10	LC	0	0	0	**0**	0	795	**795**
PM1-11	LC	0	0	0	**0**	0	339	**339**
PM1-12	LC	0	1.4	0	**1.4**	0	600	**601.4**
PM1-13	LC	0	0	0	**0**	0	228	**228**
PM1-14	LC	0	1.3	0	**1.3**	9.7	510	**521**
PM1-15	Bridge	0	0	0	**0**	59	383.8	**442.8**
PM2-1	Bridge	0	0	0	**0**	0	693	**693**
PM2-2	LC	0	0	0	**0**	0	792	**792**
PM2-3	Bridge	0	0	0	**0**	0	672	**672**
PM2-4	Bridge	0	0	0	**0**	0	394	**394**
PM2-5	LC	0	0	0	**0**	0	207	**207**
PM2-6	LC	0	0	0	**0**	0	525	**525**
PM2-7	Bridge	0	0	0	**0**	0	502.5	**502.5**
PM2-8	LC	0	0	0	**0**	0	195	**195**
Total	**All**	**0.0**	**110.3**	**0.0**	**110.3**	**264.7**	**10050.3**	**10355.9**
Average	**All**	**0.0**	**4.8**	**0.0**	**4.8**	**11.5**	**437.0**	**450.3**
Average	**LC**	**0.0**	**0.8**	**0.0**	**0.8**	**1.4**	**402.3**	**404.6**
Average	**Bridge**	**0.0**	**12.3**	**0.0**	**12.3**	**30.4**	**501.9**	**535.9**

3.2 Stream Habitat Loss

Four of the stream crossings in the PGFD, all CMPs, were impassable, resulting in a 6000 m loss of potential stream habitat. Three of the crossings (PG2-2, PG2-6, and PG2-8) were deemed impassable because of excessive flow rates through pipes. The CMPs at crossings PG2-2, PG2-6, and PG2-8 accelerated stream flows by 7.8, 4.7, and 8.2 times, respectively. On average, the rate of flow within a CMP was double that of the stream's flow rate. Note that stream flows were measured during summer low-flows. The fourth impassable crossing, PG3-3, was impassable because the outlet of the CMP was perched, and there was an insufficient pool depth (0.07 m) below the outlet from which fish could jump. There were no impassable crossings in the PMFD.

The total stream habitat loss (habitat loss due to encroachment plus benthic loss) totalled 562 m^2 in the PGFD (n=23) compared to 110.3 m^2 in the PMFD (n=23). In the PGFD, 70% of the crossings resulted in a habitat loss due to encroachment and 52% of the crossings caused a benthic loss. Only 26% of the crossings in the PMFD resulted in a habitat loss due to encroachment, and none of the crossings resulted in a benthic loss. The loss of stream habitat in the PGFD was greater than that of the PMFD due to the fact that 100% of the CMPs installed in the PGFD encroached on their respective channels and none of them were embedded (see photographs 1 & 2 in Appendix 2).

By crossing type, the average loss of stream habitat per crossing in this study was 42.5 m^2 for CMPs, 1.2 m^2 for LCs, 11.5 m^2 for bridges, and 0.8 m^2 for deactivations (Figure 5). Figure 6 illustrates the range of stream habitat losses by crossing type. It should be noted that the average loss of stream habitat for CMPs was increased by 13.2 m^2 due to crossing PG2-1 which had a loss of stream habitat of 158 m^2. Also, the bridge crossing PM1-4 caused a habitat loss due to encroachment of 83.5 m^2, elevating the average loss of stream habitat for bridges by 6.5 m^2. The average loss of stream habitat per crossing for CMPs was generally greater than that of LCs, bridges, and deactivated crossings because all of the CMPs in this study were undersized and were not embedded.

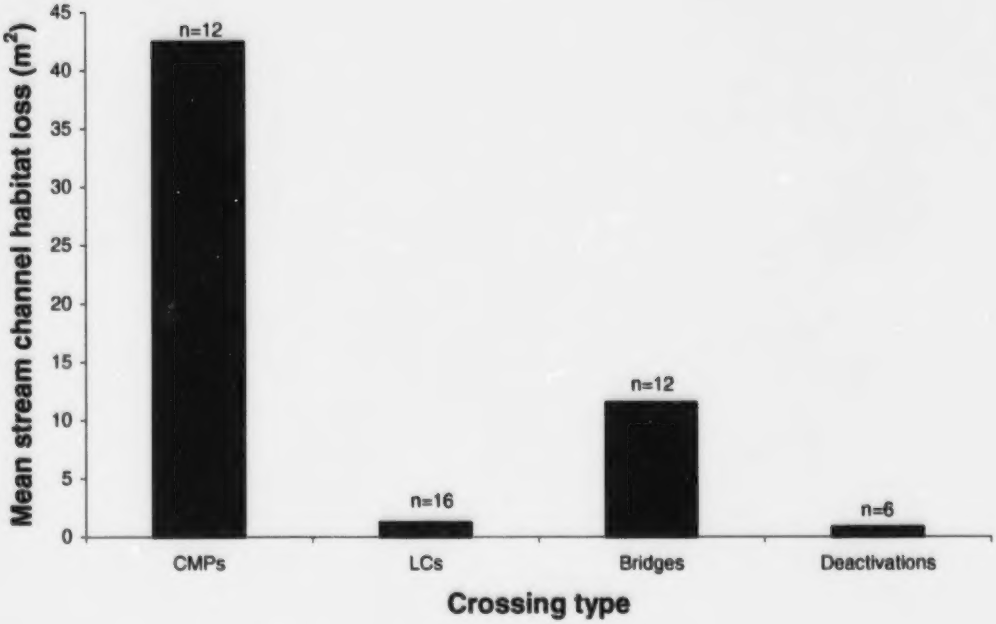

Figure 5. The average stream habitat loss by crossing type.

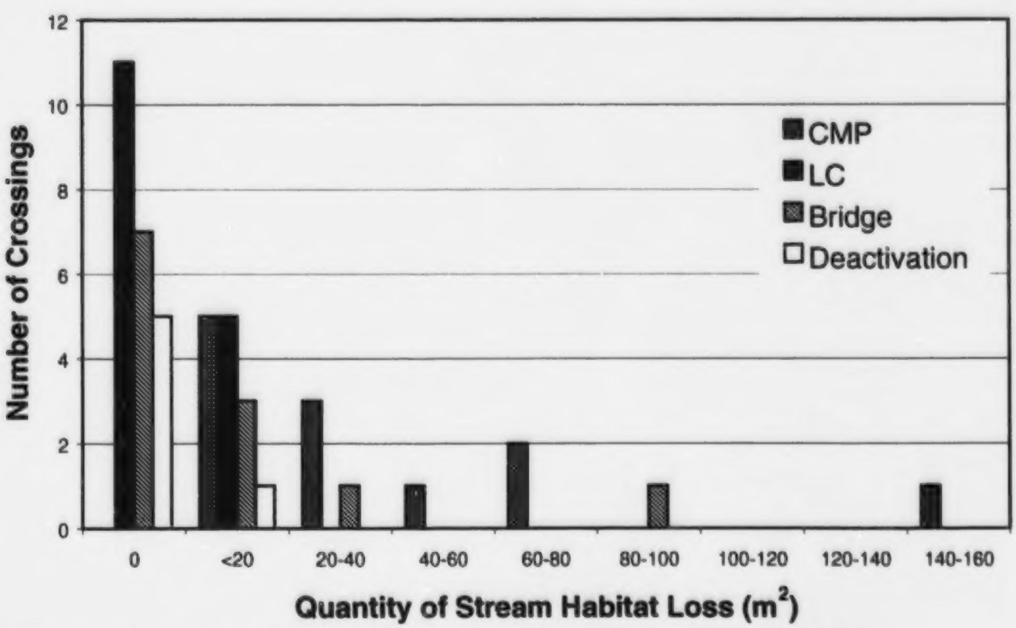

Figure 6. A histogram illustrating stream habitat loss by crossing type.

Table 5 demonstrates the encroachment ratios of the stream crossings by type (excluding deactivated crossings) as well as the percent gradient for each CMP. Table 5 also includes the encroachment ratios and percent gradients of pre-FPC CMPs that were surveyed as part of a fish passage assessment conducted in the Bowron River watershed in 1997 (Drummond, R.J. and D.G. Hickey 1997). These pre-FPC encroachment ratios and gradients were compared to those of the post-FPC CMPs of the present study. Figure 7 demonstrates the average encroachment for the pre-FPC CMPs (Drummond and Hickey 1997) and the post-FPC CMPs, LCs, and bridges surveyed in this audit. Note that a crossing with an encroachment ratio of 0.4:1 would indicate that the width of the crossing structure is 40% the bankful width of the stream while a crossing with an encroachment ratio of 1.4:1 would indicate that the width of the crossing structure is 40% greater than the bankful width of the stream.

Table 5. Summary of encroachment ratios for pre- and post-FPC code CMPs and post-FPC LCs and bridges. Percent gradients of the pre- and post-FPC CMPs are also summarized.

Pre-FPC CMPs*			Post-FPC CMPs			Post-FPC LCs		Post-FPC Bridges	
Crossing ID*	Ratio	Gradient (%)	Crossing ID	Ratio	Gradient (%)	Crossing ID	Ratio	Crossing ID	Ratio
G1-042	0.4:1	5.1	PG1-1	0.73:1	0.2	PM1-1	1.40:1	PM1-2	1.34:1
FSRSP1	0.2:1	4	PG1-6	0.90:1	0.2	PM1-3	0.74:1	PM1-4	0.60:1
GI-070	0.3:1	6	PG2-1	0.29:1	2.5	PM1-5	1.90:1	PM1-6	0.72:1
FSRSP3	1.2:1	12.1	PG2-2	0.22:1	5.8	PM1-7	1.00:1	PM1-15	3.23:1
NSSP10	0.4:1	6	PG2-4	0.65:1	2.2	PM1-8	1.24:1	PM2-1	1.89:1
NSHAG3	0.8:1	10.5	PG2-5	0.73:1	0.8	PM1-9	2.30:1	PM2-3	1.07:1
NS18M6	0.7:1	9.7	PG2-6	0.43:1	3.3	PM1-10	2.60:1	PM2-4	2.55:1
NS18M7a	0.4:1	1.6	PG2-7	0.64:1	0.5	PM1-11	1.37:1	PM2-7	2.04:1
NS18M7b	0.4:1	0.2	PG2-8	0.48:1	2.0	PM1-12	1.31:1	PG1-3	0.51:1
NS18M9	0.3:1	6.1	PG2-9	0.40:1	2.0	PM1-13	1.36:1	PG1-5	0.70:1
NS18M15a	0.6:1	4.7	PG3-3	0.50:1	0.5	PM1-14	1.29:1	PG2-3	1.35:1
NS18M15b	0.6:1	5.6	PG3-5	0.47:1	0.5	PM2-2	1.64:1	PG2-11	2.35:1
NS18M20	0.6:1	12	-	-	-	PM2-5	5.15:1	-	-
NS18M21	0.3:1	10.6	-	-	-	PM2-6	1.13:1	-	-
NS18M33	0.5:1	0.5	-	-	-	PM2-8	1.74:1	-	-
NS18M34	0.3:1	9.4	-	-	-	PG3-2	0.57:1	-	-
NS18M35	0.3:1	14	-	-	-	-	-	-	-
NS18M42	0.4:1	5.1	-	-	-	-	-	-	-
NS18M43	0.5:1	7.8	-	-	-	-	-	-	-
NS10M5	0.4:1	4	-	-	-	-	-	-	-
Average	**0.48:1**	**6.75**	-	**0.54:1**	**1.7**	-	**1.67:1**	-	**1.53:1**

Data published in *Fish Passage Assessments at Selected Stream Crossings in the Bowron River Watershed* (Drummond, R,J. and D.G. Hickey, 1997)

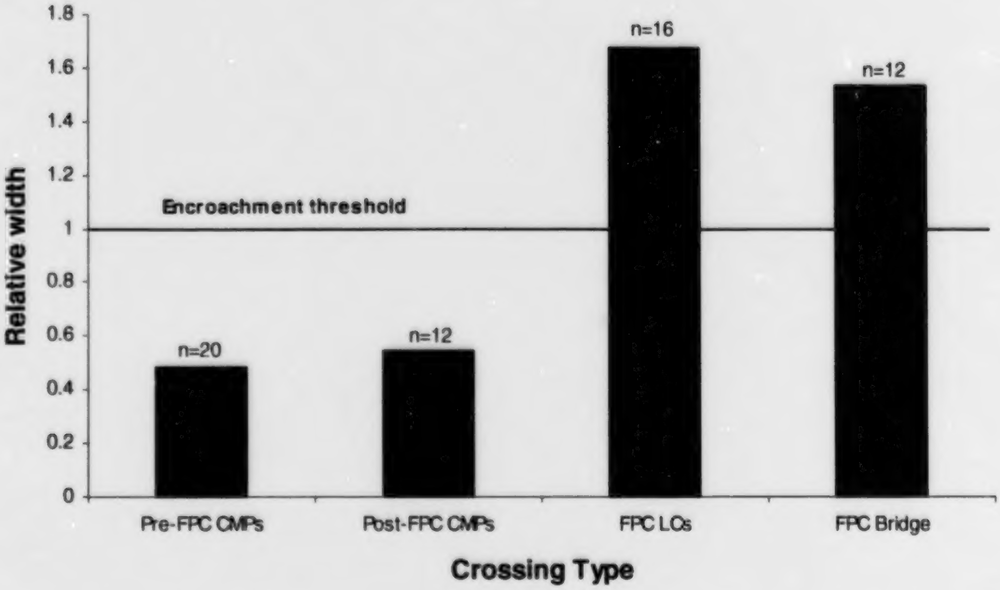

Figure 7. The average stream crossing widths relative to channel widths (i.e. stream crossing width:channel width) of pre-FPC CMPs and post-FPC CMPs, LCs, and bridges.

From Table 5 and Figure 7, it is apparent that LCs and bridges generally do not result in a stream encroachment (see photographs 3 & 4 in Appendix 2). Four of the bridge crossings reviewed did result in a habitat loss due to encroachment because their bridge decks were too short to extend across the channel properly, and as a result, required more riprap to protect bridge abutments (see photographs 5, 6, & 7 in Appendix 2). In comparing pre-FPC and post-FPC CMPs, it is clear that undersized culverts continue to be installed on fish-bearing streams in the PGFD. Moreover, 58% of CMPs reviewed by this study, all of which were non-embedded, were installed at gradients greater than the 0.5% SCG-recommended gradient for non-embedded culverts.

3.2 Riparian Habitat Loss

The average riparian loss due to crossing was 66.4 m^2 for the PGFD and 11.5 m^2 for the PMFD (Table 3 & 4). The greatest losses in this category were incurred by bridges and deactivations; for example, crossings PG1-2, PG1-3, PG1-4, PG1-5, and PM1-6 all had losses exceeding 120 m^2. The average riparian loss due to crossing structure by crossing type was 13.6 m^2 for CMPs, 2.1 m^2 for LCs, 92.3 m^2 for bridges, and 81.3 m^2 for deactivations. It should be noted that 30 of the crossings had incurred no riparian loss due to crossing. Figure 8 illustrates the range of riparian loss due to crossing by crossing type.

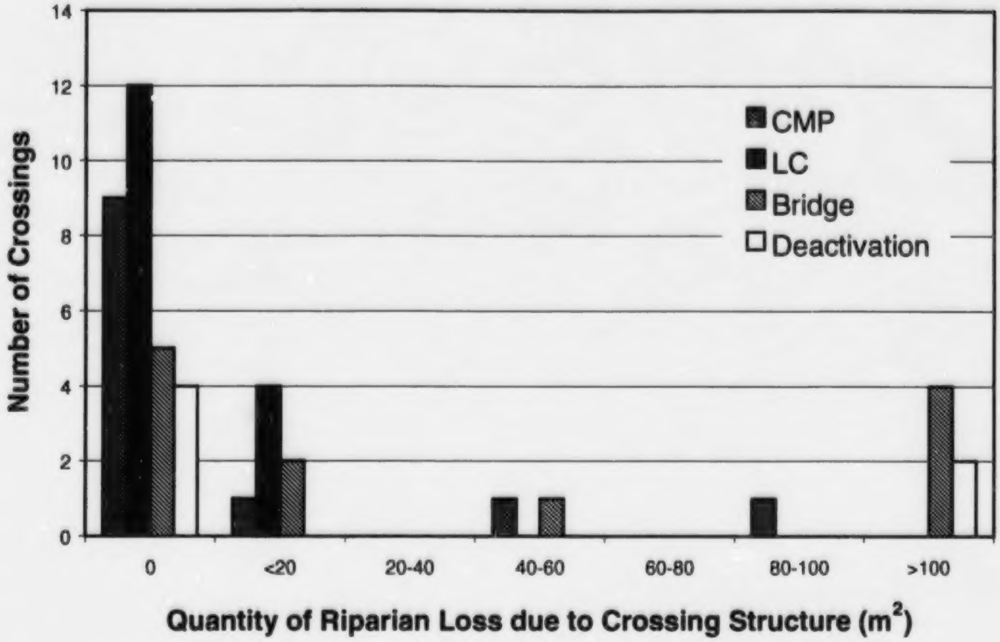

Figure 8. A histogram illustrating riparian loss by crossing type.

The riparian loss due to road varied between Forest Districts. The average riparian loss due to road was 509 m^2 for the PGFD and 437 m^2 for the PMFD. The average loss per crossing generally depends on the clearing width of the roads surveyed, and not the crossing structure itself. Crossings located on Forest Service roads -- the main access roads to cutblocks -- generally have greater riparian loss than secondary roads or spur roads because the clearing widths on Forest Service roads tend to be greater (see photograph 8 in Appendix 2). This was demonstrated in study areas PG-2 and PM-2 where most crossings were located on Forest Service roads. Table 6 demonstrates the number of crossings located on Forest Service roads and the average riparian loss due to road by study area.

Table 6. Summary of crossings located on Forest Service roads and the average riparian loss due to road by study area.

Study Area	Average Riparian Loss due to Road	No. of crossings on Forest Service Roads	Total No. of crossings surveyed in study area
PG-1	316	0	6
PG-2	726	8	12
PG-3	306	0	5
PM-1	405	3	15
PM-2	498	4	8

The average riparian loss due to road was 726 m^2 for study area PG-2 and 498 m^2 for study area PM-1. Often within cutblocks, only the width of the road (not including the right-of-way)

would be used to calculate the riparian loss due to road because all of the riparian vegetation would have been removed as part of the logging of that block.

The total riparian loss was 13,231 m^2 for the PGFD and 10,315 m^2 for the PMFD.

3.3 Sediment Control

Summaries of sediment related issues at the surveyed crossings in the PGFD and the PMFD are provided in Tables 7 and 8, respectively. Of the 23 crossings surveyed in the PGFD, 13 (56%) had sediment control concerns (e.g. see photographs 9 & 10 in Appendix 2). Six of those 13 were a result of an absence of sediment control measures and seven were due to a lack of maintenance of existing sediment control measures.

The more common sediment related problems in this district included:

- Overflowing sediment ponds (see photograph 11 in Appendix 2);
- Inappropriate application of silt fences (as a fish barrier, perpendicular to flow in the stream) (see photographs 12);
- Un-maintained ditches without gravel lining or check-dams ponds (see photographs 1, 8, & 11 in Appendix 2);
- Sediment fallout from bridge decks and unstable road fill failing into stream;
- Exposed and disturbed streambanks without re-vegetation, mulching, re-sloping, silt fencing or other bioengineering techniques.

In the PMFD, three (13%) of the 23 crossings had sediment control concerns. The cause of these concerns included sediment fallout from bridge decks and lack of erosion protection techniques on exposed streambanks. In general, the stream crossings in this district displayed good application of sediment control measures such as extensive hydroseeding, hay bales, filter fabric, and ditch flows directed into vegetation for filtering (rather than directly into the stream). The PMFD sites also had a greater retention of riparian vegetation and natural streambank integrity due to the installation of clear spanning structures.

Table 7. Summary of the sediment control issues of the surveyed crossings of the PGFD (1=yes; 0=no).

Crossing ID	Crossing Type	Sediment control Concern	Sediment control measures present	Sediment control Measures functioning	Comments
PG1-1	CMP	0	0	0	rock fill failure
PG1-2	D	0	1	1	filter fabric but no re-veg
PG1-3	B	1	1	0	bridge deck fallout
PG1-4	D	0	1	1	no re-veg
PG1-5	B	1	1	0	bridge deck fallout
PG1-6	CMP	0	0	0	
PG2-1	CMP	1	0	0	no checkdams, ditches not gravel lined, no settling pond
PG2-2	CMP	1	1	0	silt fence in creek - barrier to juveniles (0.28m drop)
PG2-3	B	1	1	0	settling ponds full and overflowing, ditches & ponds require maintenance
PG2-4	CMP	1	1	0	settling ponds full, overflowing, silt fence in creek, ponds require maintenance
PG2-5	CMP	0	1	1	settling ponds functioning, vegetation filter for outlet, ditches rock-lined
PG2-6	CMP	0	0	0	
PG2-7	CMP	0	1	1	ditches rock lined with functioning check dams, slopes grassed
PG2-8	CMP	1	0	0	high erosion potential, culvert encroaches, downstream scouring, sediment deposition
PG2-9	CMP	0	0	0	no re-vegetation
PG2-10	D	1	0	0	bridge failed-barrier, removed, machinary compacted streambanks
PG2-11	B	1	1	0	bridge deck fallout (3 inches of mud across entire deck)
PG2-12	D	1	0	0	exposed left bank, no vegetation, no seeding, no silt fence
PG3-1	D	0	1	1	both banks stable and re-vegetated
PG3-2	LC	1	1	0	road fill failing into creek, wing deflector only on one corner of crossing
PG3-3	CMP	1	0	0	road fill failing into creek,
PG3-4	D	1	0	0	no re-vegetation, sideslopes not pulled back to stable slope (currently at 45 degrees)
PG3-5	CMP(2)	0	0	0	
	Total	**13**	**12**	**5**	

Table 8. Summary of the sediment control issues of the surveyed crossings of the PMFD (1=yes; 0=no).

Crossing ID	Crossing Type	Sediment control concern	Sediment control measures present	Sediment control measures functioning	Comments
PM1-1	LC	0	0	0	
PM1-2	B	0	0	0	
PM1-3	LC	0	0	0	
PM1-4	B	0	1	1	filter fabric present, grass-seeded
PM1-5	LC	0	0	0	
PM1-6	B	0	0	0	
PM1-7	LC	0	0	0	
PM1-8	LC	0	1	1	filter fabric present to prevent erosion of road fill, hay bale in ditches
PM1-9	LC	0	0	0	slash in the creek
PM1-10	LC	0	1	1	excessive filter fabric partially blocking outlet
PM1-11	LC	0	1	1	root wad left intact under crossing, berms functioning to prevent sediment deposition
PM1-12	LC	0	0	0	slash in the creek
PM1-13	LC	0	0	0	
PM1-14	LC	1	0	0	lateral channel shift due to bank destabilization, erosion of abutments, no re-vegetation
PM1-15	B	0	0	0	no re-vegetation
PM2-1	B	1	0	0	bridge deck fallout, no revegetation on exposed soil streambanks, no guard rails
PM2-2	LC	0	1	1	filter fabric and log deflector functioning
PM2-3	B	0	0	0	
PM2-4	B	1	0	0	bridge deck fallout, no guard rails
PM2-5	LC	0	0	0	slash in the creek
PM2-6	LC	0	1	1	ditches grass seeded, no check dams or gravel lining
PM2-7	B	0	1	1	extensive hydroseeding
PM2-8	LC	0	1	1	extensive hydroseeding
	Total	3.0	8.0	8.0	

4.0 Discussion

The purpose of this audit was to determine whether the Department's goal of No Net Loss of fish habitat is being met by the forestry sector with respect to post-FPC intact and deactivated stream crossings. The audit clearly indicates that No Net Loss of fish habitat is not being achieved under the FPC. However, this audit indicates that a greater degree of fish habitat protection is being achieved in the PMFD than in the PGFD, primarily due to the differences in the predominant crossing types. It is also clear, as illustrated in the PMFD, that the majority of discrete habitat losses at each crossing site can indeed be prevented through the adoption of best management practices.

To begin with, there is a greater degree of fish habitat loss occurring in the PGFD than the PMFD, due in large part to the installation of CMPs. The installation of CMPs continues to cause significant habitat loss within the PGFD. None of the post-FPC CMPs surveyed in the PGFD were embedded, and they were all undersized relative to the bankful width of their respective channels. As a result, these stream crossings incurred a greater degree of stream habitat loss than the other crossing types surveyed. The PGFD, consequently, sustained a greater degree of fish habitat loss than the PMFD (of the crossings surveyed in the PMFD, none were CMPs). A non-embedded culvert that encroaches upon a channel permanently eliminates the natural stream banks and substrates as well as any useable spawning and/or rearing habitat and food production capabilities within its ecological footprint. Moreover, a host of indirect impacts can occur upstream and downstream of an improperly installed CMP, including bank erosion, sediment deposition on spawning grounds, and increased hydraulic instability, among others (Dane 1978).

The risk of further habitat loss upstream of a CMP increases when it is undersized and non-embedded because there is a greater likelihood that the culvert will become impassable due to increased water velocities, lack of water depth and resting pools, and outfalls created by scouring and heaving (Dane 1978; Furniss et al. 1991). Generally, as the encroachment of the CMP increases, the water velocity within the culvert can be expected to increase, eventually making the CMP impassable to fish. This was observed in this audit as 4 of the 12 CMPs were deemed impassable as a result of impassable water velocities or culvert outfalls. On average, a doubling of water velocities within the CMPs was observed due to their encroachment.

The slope at which a culvert is installed will also have an impact on fish passage. Non-embedded culverts installed at a gradient greater than 0.5% (the SCG-recommended gradient for non-embedded culverts) have a greater risk of underscouring due to piping (flowing water underneath the culvert). Underscouring results in the loss of subgrade material and the dewatering or perching of the culvert. Over half of the CMPs reviewed in this study, all of which were non-embedded, were installed at gradients greater than the SCG-recommended 0.5%.

Post-FPC practices are similar to pre-FPC practices with respect to CMP installations. In fact, this audit demonstrates that the encroachment ratios and the improper installation depths and gradients of the post-FPC CMPs reviewed in this audit are similar to those of pre-FPC CMPs (Drumond, R.J. and D.G. Hickey 1997). An audit conducted by the Prince Rupert Regional Riparian Review Team in the Prince Rupert Forest Region/Skeena Region (1997) also demonstrated that post-FPC CMPs were installed poorly (improper depth and gradient) and resulted in fish passage barriers and negative impacts on stream bank stability. Only 6 of the 29 stream crossings reviewed by the Review Team provided safe fish passage. This would suggest that the FPC and the SCG have not resulted in increased habitat protection with regards to the installation of CMPs on streams.

A significant amount of effort is currently being expended by MELP and MOF through the jointly administered Watershed Restoration Program to assess and restore fish passage at impassable stream crossings constructed prior to the FPC. MELP has even developed the *Fish Passage–Culvert Inspection Procedures* (Parker 1999) as a guide to identify fish passage barriers due to pre-FPC culverts. In fact, nine fish passage culvert inspections conducted under the auspices of the Watershed Restoration Program in the Cariboo Region have identified that access to over 400 km of fish habitat can be restored by enabling fish passage at 126 of the 264 culverts assessed (Parker 1999). While the evaluation and restoration of impassable culverts is a necessary step in repairing the damage caused by pre-FPC installations, culverts continue to be installed improperly on fish-bearing streams, despite the FPC and the SCG, and will continue to cause fish passage problems and cumulative impacts within watersheds. These continuing practices will also lead to ever-increasing maintenance and restoration costs in addition to the loss of fish habitat. Thus, it is critical to prevent habitat loss at the outset through the adoption of best management practices and the implementation of environmental legislation and policy.

There were no post-FPC CMPs observed on fish-bearing streams within the PMFD. The licensees in the PMFD continue to use LCs and bridges as an effective alternative to CMPs. Log culverts are more ubiquitous on the coast given the availability of western red cedar, the most suitable species for LC construction. The LCs surveyed in the PMFD were installed as per the directions of the FPC and the SCG, such that there was little-or-no loss of stream habitat. The LCs retained the natural streambed, the stream bank integrity, and the natural meander pattern of the stream. Moreover, LCs do not require instream work during construction and deactivation, thus preventing all associated problems with respect to instream work. Any stream habitat losses observed were caused due to improper placement of the sill logs. The LCs had the least impact on fish habitat of the four crossing types surveyed in this audit.

The bridges surveyed within the PMFD were also installed according to the FPC and the SCG, such that there was generally limited-to-no loss of stream habitat. The bridges inspected also retained the natural streambed, stream bank integrity, and the natural meander pattern of the stream. The bridges within the PGFD were also installed as per the FPC and the SCG, yet on small streams (S3 and S4 streams), the bridges of the PGFD tended to be shorter than those of the PMFD (9 m vs 15 m). The short length of the bridges in the PGFD resulted in a larger footprint because the abutments of these bridges were set closer to the stream channel and required more riprap to provide scour protection. The greater amount of riprap used at the PGFD bridge crossings resulted in increased habitat losses due to encroachment and riparian loss due to crossing. Conversely, the longer bridges of the PMFD had abutments that were set sufficiently back from the top of the streambanks, avoiding the unstable nature of the streambanks, requiring less riprap, and resulted in a smaller ecological footprint. While bridges are the preferred fish passage structure of the SCG, they do have the potential to cause greater footprints than other crossing structures as they are often "over-engineered". Road builders must install longer bridge spans in order to avoid using excessive amounts of riprap for scour protection.

The streambanks of the deactivated crossings surveyed in the PGFD were often left un-vegetated with nothing done to prevent soil erosion. This can result in significant sediment control problems. Under the FPC Forest Road Regulation, streambanks must be re-vegetated. On larger S2 deactivations, riprap that had been installed to protect the crossing structure from scour was left at the site, resulting in a permanent loss of riparian vegetation.

While LCs and bridges are better than CMPs in terms of reducing fish passage problems and minimizing ecological footprints, all crossing types, including deactivations, continue to incur large losses of riparian vegetation. Riparian vegetation is crucial to fish as it provides food and cover, regulates the water temperature, and stabilizes the streambanks. While it is expected that at each crossing site there will always be a loss of riparian habitat due to the road and the crossing structure, the clearing of riparian vegetation within the right-of-way (ROW) adjacent to stream crossings should be minimized. The road clearing widths (including a 5 m road and the ROW clearing) are governed by several different factors, including slope gradient, winter clearing, and safety, among many others. Road clearing widths of 20 to 30 m were observed at crossings in both the PGFD and the PMFD. These clearing widths were observed on roads that were situated on slopes with low gradients (0-5%) where safety concerns were minor. These ROW widths are more appropriate for roads situated on slopes with gradients of 30 to 40% (Forest Road Engineering Guidebook, MELP 1995). Therefore, it is apparent that the clearing of riparian vegetation within the ROW adjacent to the crossing could be reduced or tapered at the crossing site.

The retention of trees within the ROW adjacent to the stream crossing is also one of the most effective ways of minimizing sediment impacts from the road while maintaining many of the streams natural characteristics at the crossing site (Chillibeck *et al.* 1992). Roads and stream crossings are major sources of sedimentation in streams, and most of the sedimentation at stream crossings (70%) occurs in the first year, during and immediately after construction (Furniss et al. 1991; Poulin and Argent 1997). At most of the crossing sites surveyed by this audit, cleared ROWs adjacent to the stream crossing had not been replanted with native shrubs or trees and had no sediment control techniques. Sediment control techniques -- settling ponds, silt fences, and hay bales -- that had been placed within the ROW adjacent to the crossing were failing or were not being maintained for the most part. Increased retention of the riparian zone within the ROW is required if sediment production is to be controlled and fish habitat is to be conserved.

Sediment control measures were generally poorer in the PGFD than in the PMFD, partly due to lack of maintenance and partly due to inappropriate or inadequate sediment control measures. The lack of adequate sediment control measures in the PGFD was exacerbated by the prevalence of unstable and highly erodible glacio-lacustrine soils. In some cases, the improperly implemented sediment control techniques observed in this audit had the potential to cause more damage to fish habitat than if none were applied at all (e.g. silt fences installed across the entire channel, perpendicular to flow, creating a barrier for juvenile fish). These poor practices continue despite the current environmental legislation, policy, and guidelines. In contrast, the sediment control measures implemented in the PMFD were considerably better. The installation of clear spanning log culverts as opposed to CMPs resulted in less channel encroachment, retention of more riparian vegetation and maintenance of streambank integrity, which collectively reduces the degree of sediment control measures required from the outset. In general, the level of effort for habitat protection was greater in the PMFD than the PGFD, both on the process level (the provision of fisheries information and clarity of Forest Development Plans) and on the operational level (e.g. individual S4 streams both on and off cutblocks were identified as fish bearing with fish stream signage similar to that used in urban areas).

This audit demonstrates that No Net Loss of fish habitat is not being achieved at post-FPC stream crossings. The total loss of stream habitat from the 46 crossings was 672 m^2 (not including loss due to impassable crossings). If riparian loss is included, the total habitat lost due to the 46 crossings amounts to 24,820 m^2, 539 m^2 per crossing. With the construction of 5000 to 10,000 km of new forest roads each year and the installation of approximately one stream

crossing for every 1.4 kilometres of road built (Geographic Data BC, TRIM 1979-1988 pers. comm.; Ministry of Forests, 1998), it can be conservatively estimated that 3000 to 6000 crossings are installed every year. If only a tenth of those newly installed crossings are installed on fish-bearing streams, the province of British Columbia is losing between 162,000 to 324,000 m^2 of fish habitat per year due to stream crossings on forest roads, 43,800 to 87,600 m^2 of which is stream channel habitat alone.

5.0 Conclusion

Knowledge of the impacts of stream crossings on fish habitat are well established, as are the best management practices to mitigate these impacts. Despite this knowledge, there is a continued lack of compliance with fish habitat protection legislation and policy with regards to stream crossings. The preamble to the FPC supports the sustainable use of the forests and states that sustainable use includes, "conserving biological diversity, soil, water, fish, wildlife, scenic diversity and other forest resources"(FPC 1995). The FPC further prevents the deposit of debris or erodible soil into streams and ensures safe fish passage through stream crossings. This audit demonstrates that the FPC objectives are not being met with respect to stream crossings. The destruction of fish habitat is prohibited by the *Fisheries Act*, and DFO's guiding principle is to achieve No Net Loss of the productive capacity of fish habitat. No Net Loss of fish habitat cannot be achieved with current stream crossing practices. A greater degree of fish habitat protection must be achieved on post-FPC stream crossings, underscoring the need for significantly increased monitoring and maintenance of stream crossings and enforcement of environmental legislation.

6.0 Recommendations

This audit reviewed the stream crossing practices in both the Prince George Forest District (PGFD) and the Port McNeill Forest District (PMFD). The PGFD and the PMFD provide an adequate representation of forestry practices, forest licensees, and ecology in both coastal and interior British Columbia. The results of the audit provide a comparison of different crossing types with respect to their impacts on fish habitat and a means to make recommendations to improve our protection of fish habitat.

The recommendations of this audit are as follows:

CMPs continue to be installed improperly, at least within the PGFD, and contrary to the SCG, CMPs are not viable for small stream crossings. Most of the stream habitat loss from stream crossings occurs on smaller S3 and S4 streams as a result of improperly installed CMPs.

- Agencies responsible for the protection of fish habitat and stream crossings (i.e. DFO, MELP, and MOF) should adopt the position of not allowing the installation of CMPs on fish-bearing streams. There are better alternatives in terms of both providing fish passage and protecting habitat at crossing sites, including LCs and bridges. This has been recognized for several years, yet poor practices with regards to CMP installation continue.
- Bridging systems and spanning, open bottom culvert systems should be used on S3 and S4 streams.
- If bridging systems are used, it must be recognized that they can potentially create ecological footprints that are much larger than necessary. This usually occurs when bridge spans are too short to span the stream and its banks. Road builders should be made aware that longer spans will reduce the size of the footprint at the crossing site because less riprap is required to provide scour protection since abutments can be set sufficiently back from the top of the streambank.
- If CMPs are to be installed on fish-bearing streams, they may require an authorization under section 35(2) of the *Fisheries Act* since they have a high likelihood of causing a harmful alteration, disruption, or destruction to fish habitat. This in turn would trigger an environmental assessment, at cost to the proponent, under the *Canadian Environmental Assessment Act*.
- If CMPs are to be installed, DFO and MELP should establish a referral protocol within Forest Districts to ensure that an adequate review of the potential fish habitat impacts due to CMP installations is achieved.
- If CMPs are to be installed on fish-bearing streams, an independent environmental monitor should be required at each installation to ensure that the CMPs are installed to achieve a No Net Loss of fish habitat, more specifically, that they are the proper size (as not to encroach on the stream channel), embedded, and installed at the proper gradient.
- Where stream crossing structures have resulted in habitat damage or barriers to fish passage, regulators should consider their options under the *Fisheries Act*. Works that have harmed fish habitat, or resulted in sediment deposition, may result in charges under section 35 or section 36 of the *Fisheries Act*. Alternatively it may be possible to require the operator to refit a stream crossing structure so that it allows for the passage of fish, pursuant to section 20 of the *Fisheries Act*.
- Agencies responsible for the protection of fish habitat and stream crossings should focus on increasing monitoring and enforcement of post-FPC stream crossings.
- DFO should be involved in promoting the protection of fish habitat within existing forest practices training programs. Workshops relating to stream crossing best management

practices should be conducted. These workshops should involve the key agencies responsible for the protection of fish habitat and stream crossings and forest licensee personnel within each of the Forest Districts.

Deactivated crossings are not being rehabilitated properly. Generally, deactivated crossing sites did not have adequate sediment control measures and were not adequately re-vegetated.

- Road builders should be made aware that current crossing deactivation methods are inadequate and must be required to re-vegetate deactivated crossing sites.
- Accepted deactivation techniques should be developed by DFO and MOF and incorporated into a DFO-endorsed SCG.

All crossing types continue to incur large losses of riparian vegetation. Riparian vegetation is crucial to fish as it provides food and cover, regulates the water temperature, and stabilizes the streambanks. Retention of the riparian vegetation within the ROW is the most effective means of controlling sediment and erosion concerns and streambank destabilization. There is ample evidence that a ROW vegetation can be safely maintained around stream crossings.

- The tapering of ROWs where practical should be made a required practice and adopted by the forestry sector. ROWs should be tapered at least 15 m back from the streambanks such that there is ample riparian vegetation surrounding the stream at the crossing site.
- If riparian vegetation has to be removed from within the ROW at the crossing site, attempts should be made to re-vegetate the ROW as soon as conditions are appropriate (i.e. the first growing opportunity) and to install the appropriate sediment control measures.
- If sediment control measures are installed at crossing sites, a greater effort on behalf of the licensees is required to maintain these measures.

This audit demonstrates that the practices in the PGFD are generally poorer than in the PMFD. The DFO HEB Area encompassing the PGFD (the Upper Fraser HEB Area) also encompasses seven other Forest Districts. Currently, habitat management staff in the Upper Fraser HEB Area cannot adequately review all stream crossing referrals or conduct a sufficient number of inspections on stream crossings.

- Strategies to address these deficiencies in the Upper Fraser HEB Area, including more habitat management staff and enforcement personnel, should be explored.

Finally, the SCG continues to create problems in that it is just that: a guidebook. Licensees are not required to use the SCG prescribed techniques at stream crossings. DFO habitat management staff are concerned that the most recent edition still supports the use of CMPs on fish-bearing streams and that the SCG-prescribed techniques for stream crossings are not protecting fish habitat.

- The current edition of the SCG is unacceptable and should not be endorsed by DFO until all concerns are addressed.
- A workshop including key technical personnel is required to address the current problems with the SCG.

7.0 Acknowledgments

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Appendix 1

The NNL Stream Crossing Audit Form consisted of Site Information, a Crossing Survey, a Habitat Survey, and a Photographic Record. The Crossing Survey varied depending on the crossing type -- culvert, bridge, or deactivated crossing.

NNL Stream Crossing Audit – Prince George Forest District

Site Information:

Crossing Identification:

Date:		Licensee:	
TRIM Mapsheet:		Cutting Permit:	
UTM Zone:		Cut Block:	
UTM (east):		Road Name:	
UTM (north):		Road km:	
Watershed Name:		Access:	

Culvert Survey:

Type:	
Length (m):	
Span (mm):	
Encroachment Ratio:	
Embedment (m):	
Culvert Water Depth (m):	
Outlet Water Velocity (m/s):	
Culvert Gradient (%):	
Inlet Condition:	
Outlet Condition:	
Internal Condition:	
Bank Stability:	
Upstream Right:	
Upstream Left:	
Downstream Right:	
Downstream Left:	
Riparian Loss due to crossing (m^2):	
Upstream Right:	
Upstream Left:	
Downstream Right:	
Downstream Left:	
Habitat Loss due to encroachment (m^2):	
Benthic Loss (m^2):	
Habitat Loss due to impassable crossing (m):	
Riparian Loss due to road (m^2):	

Total Loss of fish habitat, excluding road (m^2):	
Total Loss of fish habitat (m^2):	

Bridge Survey:

Length (m):	
Width (m):	
Clearance (m)	
Superstructure	
Abutments	
Encroachment Ratio:	
Outlet Water Velocity (m/s):	
Bank Stability:	
Upstream Right:	
Upstream Left:	
Downstream Right:	
Downstream Left:	
Riparian Loss due to crossing (m^2):	
Upstream Right:	
Upstream Left:	
Downstream Right:	
Downstream Left:	
Habitat Loss due to encroachment (m^2):	
Habitat Loss due to impassable crossing (m):	
Riparian Loss due to road (m^2):	
Total Loss of fish habitat, excluding road (m^2):	
Total Loss of fish habitat (m^2):	

Deactivation Survey:

Bank Stability:	
Right:	
Left:	
Unstable sidecast fill pulled back to an appropriate angle (Y/N):	
Soil erosion control (Y/N):	
Revegetation of banks (Y/N):	
Side ditches blocked appropriately (Y/N):	
Loss due to encroachment (m^2):	
Benthic Loss from deactivation (m^2):	
Remaining Riparian Loss due to crossing (m^2):	
Habitat Loss due to impassable crossing (m):	
Riparian Loss due to road (m^2):	
Total Loss of fish habitat, excluding road (m^2):	
Total Loss of fish habitat (m^2):	
Deactivated to appropriate standards:	

Habitat Survey:

Stream Classification:	
Fish Habitat Classification:	
Channel Morphology:	
Large Woody Debris (%):	
Avg. Water Velocity (m/s):	
Stream Gradient (%):	

Stream Dimensions (m):	U1	U2	U3	D1	D2	D3	Average
Wetted Width:							
Water Depth:							
Bankful Width:							
Bankful Depth:							

Bed Materials (%):	Fines	Gravels	Cobbles	Boulders	Bedrock

Bank Stability:

Upstream Right:	
Upstream Left:	
Downstream Right:	
Downstream Left:	

Photographic Record:

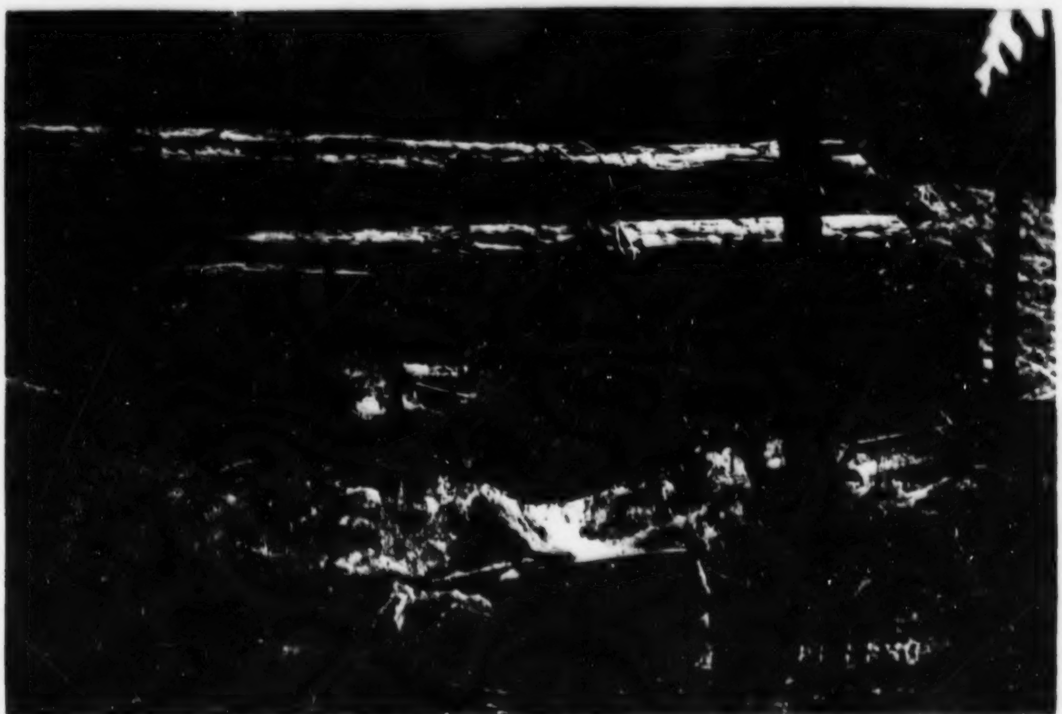
Photo:	Roll	Negative	Description
Inlet:			
Upstream:			
Outlet:			
Downstream:			
Upstream Banks:			
Downstream Banks:			
Other:			
Other:			
Other:			

Comments:

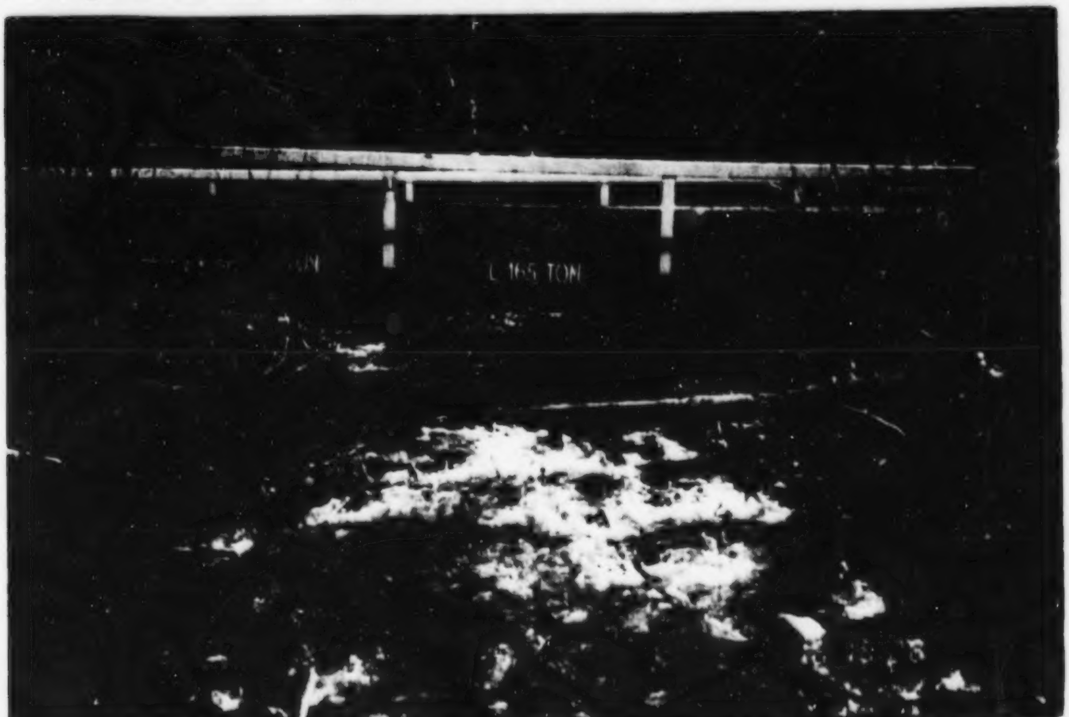
Appendix 2

Photograph 1. Stream crossing PG2-2. The 0.750 m wide post-FPC CMP was only 22% of the width of the bankful width of the stream channel (3.45 m). This resulted in a velocity barrier and an outlet barrier.

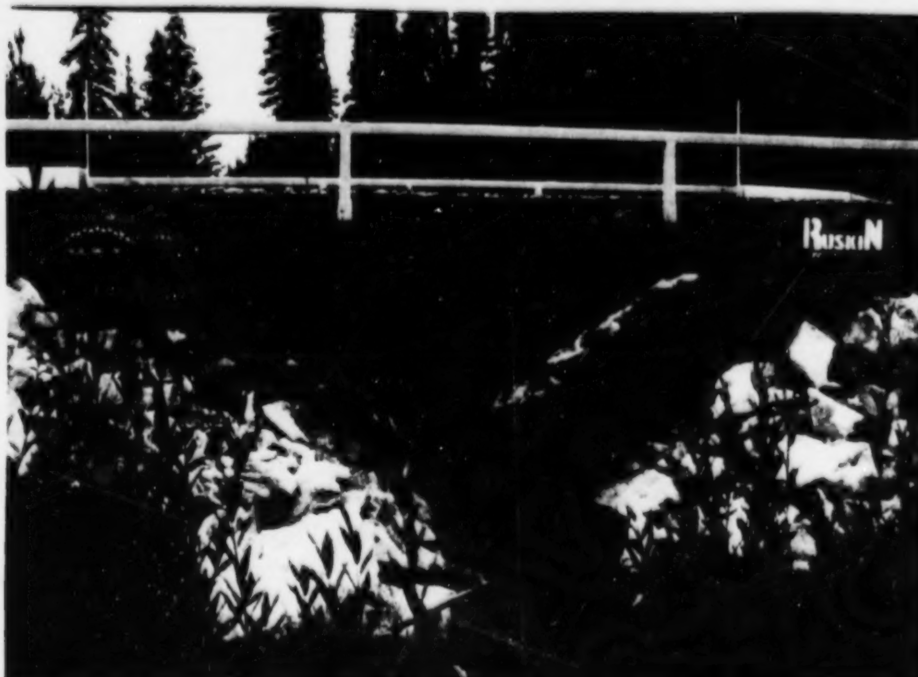
Photograph 2. Inlet of culvert at stream crossing PG2-1. The crossing width was only 29% of the channel width. Note that the ditchline flows directly into the creek.



Photograph 3. Upstream view of crossing PM2-8 showing benefits of LC technique. Note the crossing width was 1.74 times greater than the channel width (2.19 m).



Photograph 4. Stream crossing PM2-3. This crossing width was 1.35 times greater than the channel width. Streambank integrity was maintained.

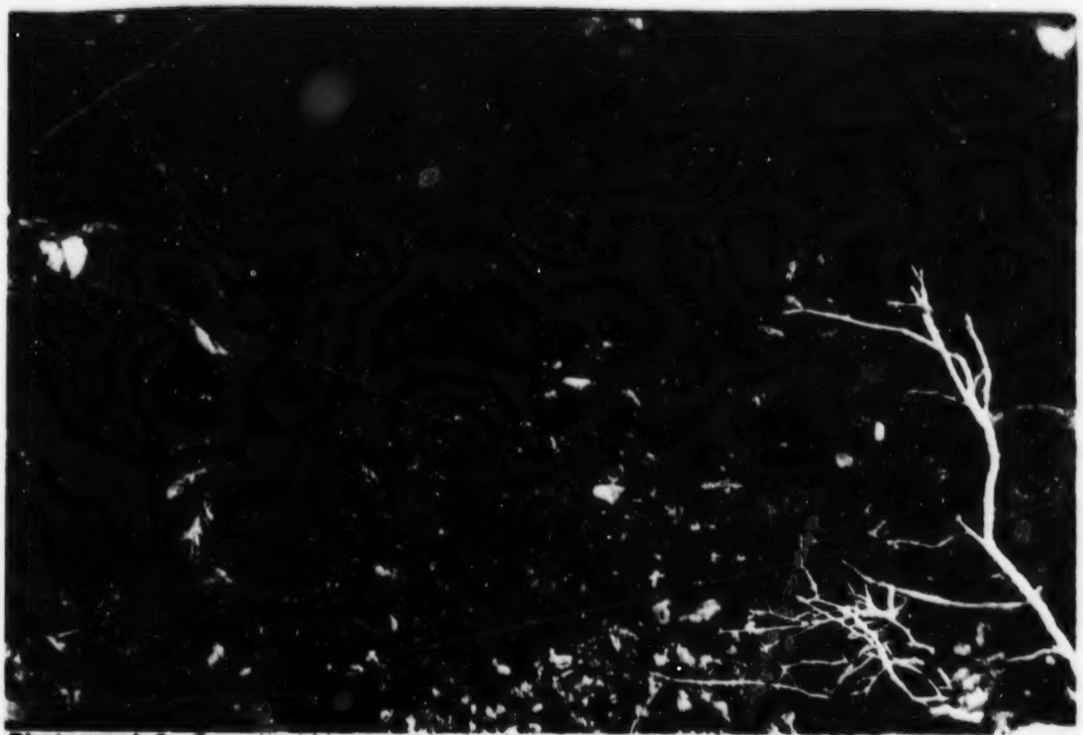


Photograph 5. Stream crossing PG1-3. Note the excessive rip-rap placed on the streambanks. The crossing width was only 51% of the stream channel.

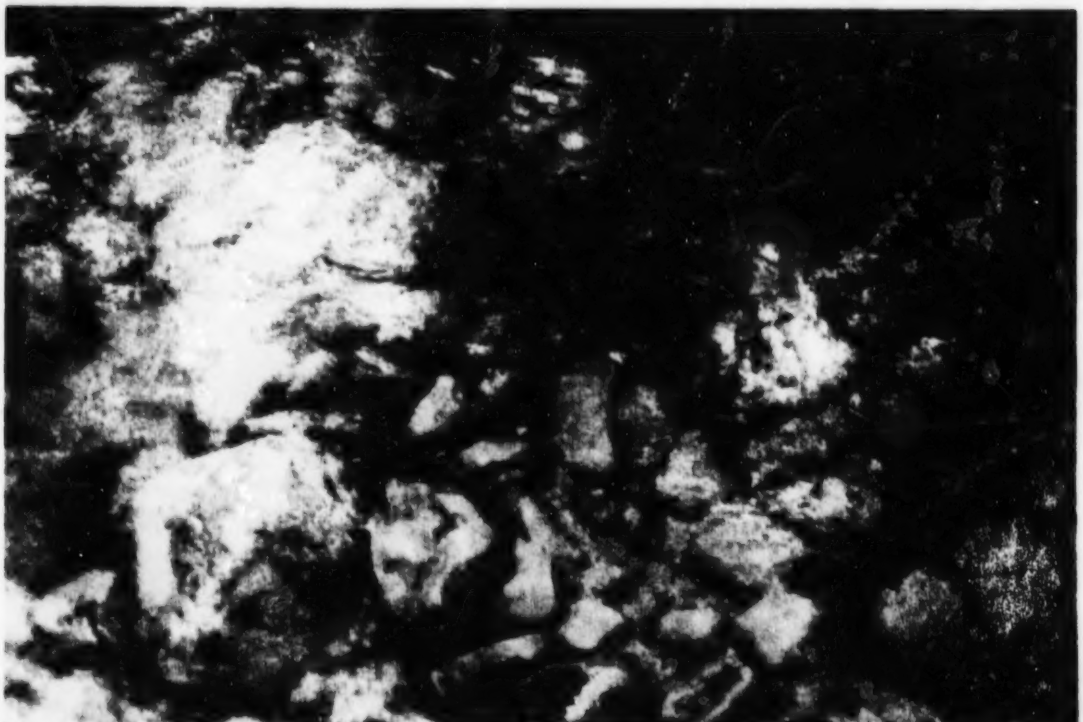
Photograph 6. Downstream view of crossing PM1-4. This crossing width was 60% of the channel width. Note the encroachment due to the right approach.

Photograph 7. Stream Crossing PG1-5. Note the excessive rip-rap placement in foreground and corresponding permanent loss of riparian vegetation.

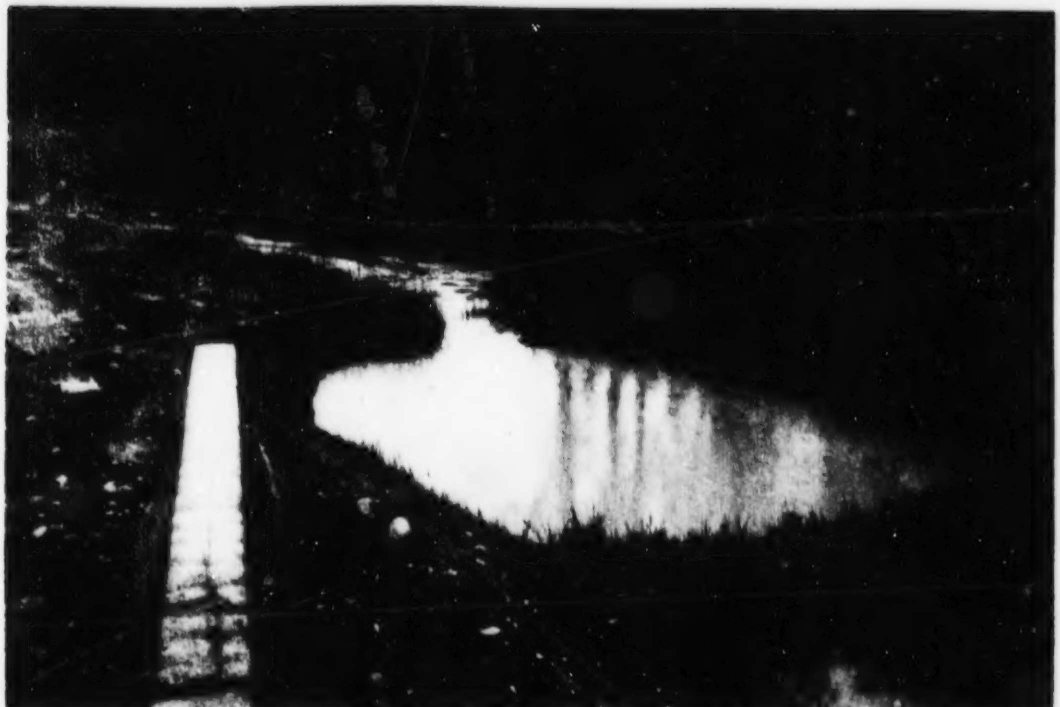
Photograph 8. Downstream banks at stream crossing PG2-1. Note the width of the right-of-way and the excessive rip-rap adjacent to the creek.



Photograph 9. Gravel/cobble streambed substrate upstream of culvert PG2-1.



Photograph 10. Sediment inundated gravel/cobble substrate downstream from stream crossing PG2-1.



Photograph 11. Over-flowing settling pond and sediment clogged ditches that flow directly into the stream at crossing PG2-3.

Photograph 12. Silt fence improperly installed in the stream channel downstream of crossing PG2-2. The silt fence resulted in a 0.28 m vertical obstruction.